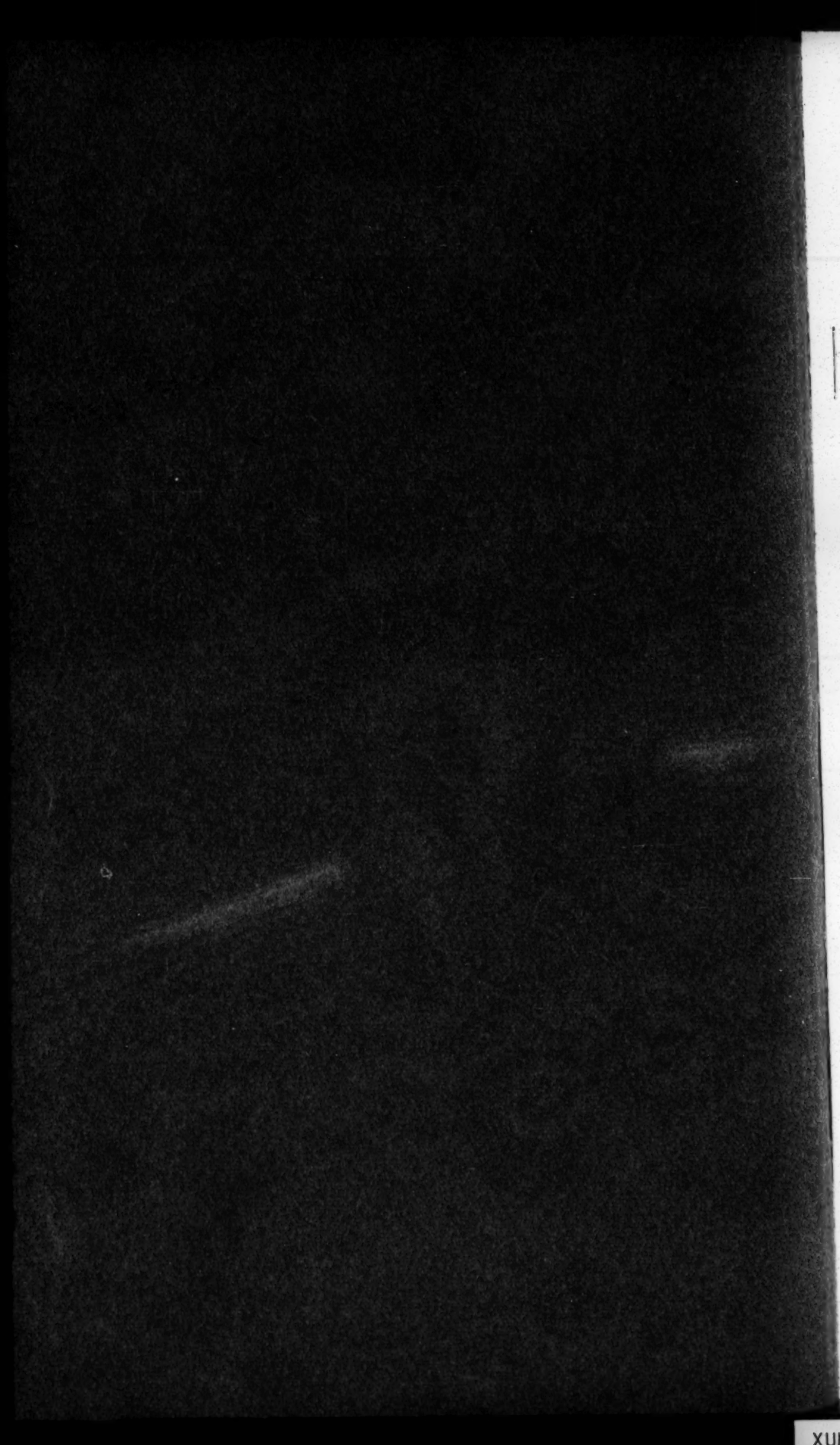

VOL. III, PP. 41-52 MAY 1, 1891

THE

NATIONAL GEOGRAPHIC MAGAZINE

GEOGRAPHY OF THE AIR.

ANNUAL REPORT BY VICE-PRESIDENT

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(Presented to the Society January 23, 1891.)

In fulfilling the duties growing out of his official position in connection with this Society, your Vice-President of the Geography of the Air has been so closely occupied with executive and other official duties devolving upon him as to preclude his giving that amount of time and labor to this annual report that the subject merits. Indeed, no report would be submitted this year had it not seemed better to insure a continuity of these annual addresses, even if one of them might not be up to the high standard which should be maintained for them.

It must have impressed every general reader of scientific journals that the past year has been marked by the publication of an unusual number of controversial articles relating entirely or in part to meteorology. Some of the discussions of this subject appear to be in the nature of speculation, which, by good authority, is defined to be "chiefly the work of the imagination, and has little to do with realities." The status of the meteorological discussion which has been going on for some time seems to be this: A number of men, applying themselves to investigation in separate branches or stages of the same science, are attempting to reconcile their views, which, based as they are upon entirely different processes of investigation, are not entirely accordant. Some, at least, of these writers are still apparently groping in the preliminary, the "natural history" stage of the

science of meteorology, while one alone stands as the exponent of the "natural philosophy" of meteorology.

To me it seems that it could not have failed to impress any interested reader who has followed the late publications on the convectional theory that, in order to clear the ground for definite meteorological discussion, it is necessary to determine the exact meaning of the various technical terms employed by the various writers. Whether from looseness of verbiage originally or from the not infrequent habit of disputants when worsted to change their ground by claiming to be misunderstood, we find that some writers are unwilling either to stand by their first criticisms or to openly abandon them; they prefer to explain away their defective statements and gradually shift around to positions almost diametrically opposed to those originally assumed.

The generally accepted theory as to cyclones attributes their initiatory formation to an unequal distribution of temperature with resulting mean diminution of pressure, and the movement of the air from places of high to places of low pressure, the lower air ascending with a gyratory motion, while air particles moving from opposite directions form couples which produce rotation. When energetic motions raise the ascending air to such a height that the temperature, cooled dynamically in ascending, goes below the dew-point, then the great store of latent heat thereby set free becomes, it is assumed, the main source of energy in maintaining the upward convectional movement. The subsidiary causes are attributed to the diminution of pressure on the collapse of the vapor, and also to the direct absorption of the sun's heat at the upper cloud surface.

In anticyclones a slow gyratory descending motion of the air is assumed. Ferrel considers the cyclone and anticyclone one system, and believes that air flowing into the cyclone from a "high" at the ground passes out into the higher atmospheric strata.

Dr. Hann has put forth the hypothesis that the genesis of cyclones and anticyclones may be sought in the general atmospheric circulation through a difference of temperature of the air from the equator to the poles. He speaks of a congestion in the upper or anti-trade winds, where the air heaps up to a great height, this being the cause of the anticyclones; and he maintains that the low temperature of the "high" is due to ground radiation, and that no part of the high pressure is the result of low temperature.

To this hypothesis of Dr. Hann, ascribing the genesis of storms to the general circulation of the atmosphere, no application of the laws of dynamics has yet been made with a view of developing it into an acceptable "theory." If it should be established it does not follow that it will in any way affect the truth of the commonly accepted "convectional system," which, founded as it is on the well-known laws of thermo-dynamics, is not likely to be successfully assailed. There may be an improved nomenclature for the laws of statics and dynamics that will express to the mind more clearly the relation of cause and effect; but until the advance of scientific research modifies the present formulation of these laws the convectional theory will be generally accepted as giving the true interpretation of all the phenomena to which it could be applied.

Professor Russell, in commenting on this subject, expresses the opinion that the low temperature is due to the convective interchange of air at a low temperature in the upper strata with air of a high temperature in lower strata, such convective interchange tending to make the whole body of air of a temperature coinciding throughout with the adiabatic rate of upward diminution, with the consequent result of rendering the air at the surface of the earth cooler than previously and the upper air warmer. When the upward diminution of temperature is less than the adiabatic rate, in the forced circulation of air crossing a mountain ridge, there occurs the dynamic heating which is observed in the case of the foehn winds. The low temperature near the earth he does not believe could ever be entirely produced by nocturnal radiation from the ground. The high pressure, in his opinion, is largely the result of greater density due to low temperature, as is very clearly indicated by the fact that the temperature is almost inversely proportional to the pressure, and that the places of lower temperature substantially coincide with the places of greatest pressure.

In advancing hypotheses and inviting discussion the real object is, or at least should be, to discover the essential cause or causes which determine the initial formation and subsequent maintenance and progress of the cyclone. Some real progress in charting lines of equal density seems to have been made by M. Nils Ekholm following Professor Abbe's system of "isostaths," one using the term density, the other buoyancy. Professor Abbe also introduces the factor of the orographic gradient, but the

latter is simply the measure of a resistance. The objection to this form of determination is this, that it is a measure of mass only. The density of two masses of air is determined to be the same; but as the density may result from two entirely different causes, their physical relations cannot be fully expressed in units of gravity. The methods of Professor Abbe and of M. Nils Ekholm undoubtedly give good results, partly from the coincidence that humidity usually varies directly as the temperature.

The method proposed by Captain James Allen in 1888, which is briefly described in appendix 24 to the annual report of the Chief Signal Officer for 1890, appears to afford the means of more clearly expressing the relations that exist between the mass of the atmosphere and the forces available for the generation and movement of storms. Its tentative application at the Signal Office has anticipated and explained storm movements not indicated or accounted for by the usual methods.

As pertinent to this matter, there is instanced a study of the progress of thunder-storms made by Berg, who observes that the line of storm front in every case investigated made a decidedly conspicuous bend into the densest part of the lines representing the absolute humidity.

Scientific conditions have so changed that in these later years it becomes more and more difficult for investigators to publish any work which may be characterized as *magnum opus*. Under this head, however, must be classed Buchan's important memoir on the distribution of atmospheric pressure, temperature, and wind direction over the whole world; a large quarto volume, which contains much new material. It has been incorporated with the results of observations during the Challenger expedition, in which series this work appears. The isobars and isotherms for each month in the year for the whole earth are charted on Mercator's projection, and for the northern hemisphere on a chart constructed on a polar projection. In connection with an abstruse subject, to which Buchan has paid so much attention, the diurnal variation of pressure, he opines from the Challenger observations that the oscillations are due to the heat taken from the solar rays directly in passing through the air and instantaneously communicated through the whole mass from top to bottom by heating and evaporation of water on innumerable dust particles. The afternoon minimum, he thinks, is caused by upward currents removing a portion of the lower air. Marked

differences exist between the continental and insular types, since on islands the morning minimum is unusually large and the afternoon minimum so small as to disappear, while in continental types the reverse conditions obtain.

Werner Von Siemens, in answering Sprung's criticism on his general air currents, after repelling certain statements of Sprung, describes his own theories, which are worthy of restating:

1. All winds are caused by the disturbances of indifferent equilibrium, and the motion of the air is to restore equilibrium.

2. These disturbances are caused through overheating of the layers of air near the surface of the earth by insolation, through unsymmetrical cooling of the higher layers by radiation, and through the heaping up of air masses caused by obstructions.

3. The disturbances are adjusted by ascending currents, wherein the particular species of acceleration occurs in which the increase of velocity is proportioned to the diminution of pressure.

4. The upward currents correspond to equally great descending currents in which there is a decrease of velocity corresponding to the acceleration in the upward velocity.

5. If the region of overheating of the air is limited locally, a local upward current reaching to the highest layers of air arises, and whirlwinds appear with interior spirally ascending currents and outside similar spiral descending currents. The result of this is dispersion of the superfluous heat of the lower air by which the adiabatic equilibrium is disturbed throughout the whole column of air taking part in the whirling motion.

6. In case the region of disturbance of the indifferent (or adiabatic) equilibrium is very extensive, as, for example, the whole of the tropical zone, the temperature adjustment can no longer be accomplished by locally ascending whirls, and a whirling current must then arise involving the whole atmosphere. The same conditions apply to these as to the local whirls of accelerated upward motion and retarded descent in such a manner that the velocity at different altitudes arising from heat converted to work is approximately proportional to the prevailing pressure at the place.

7. In consequence of the meridional motion produced and maintained by conversion of heat into work, the whole atmosphere in every latitude must rotate with approximately the same absolute velocity. Thus the meridional currents produced by overheating combine with the currents embracing the whole

wind system of the earth, with the result of disseminating the excess of temperature and humidity of the torrid zone over the temperate and arctic zones, thereby producing the prevailing winds.

8. This is accomplished by the production of alternating local depressions and elevations of barometric pressure by the disturbance of indifferent equilibrium in the upper layers of the air.

9. "Highs" and "lows" are a consequence of the temperatures and velocities of the upper currents.

Whence it follows that the most important problem of meteorology is the investigation of the causes and consequences of the disturbance of indifferent equilibrium of the atmosphere, and the weightiest problem in weather prediction is the investigation of the geographical origin or extraction of air currents pursuing their course above us toward the pole.

In Pomortsew's treatise on synoptic meteorology, published in Russia, there are full chapters on prediction of weather, whether from synoptic charts, from observations at a single place, or from prognostics of great length based on researches on the succession of warm and cold months. It also contains Pomortsew's investigations on the types of pressure distribution in eastern Europe, as well as the average path of cyclones.

The favorable opportunities afforded by the Eiffel tower have been utilized by French meteorologists. M. Angot states that during the anti-cyclone of November, 1889, the temperature on the tower was several degrees higher than below. The change of weather set in earlier, with a strong and warm wind, on the tower, while the air at the ground was cold and calm. Wind observations on the tower show a ratio of 3.1 at that height (303 meters) to the velocity at a height of 21 meters, as determined from 101 days' observations, which, remarkable at such a small height, discloses the peculiarity of high mountain stations.

Partsch, writing on evidence of climatic changes within historical times in the Mediterranean region, remarks that too much attention has been given to changes in crops, the introduction of plants, and the limits of domestic animals. He states that existing information as to the harvest time of ancient days indicates an unchanged climate, while the land-locked lakes in Tunis, which afford the best evidence on rainfall variation, show absolutely no climatic change.

Van Bebber, in writing on weather types, claims that a line drawn from the center of a cyclone perpendicularly in the direction of the heaviest gradients will in general be perpendicular to the subsequent path of the "low," and that these lows leave high temperature on the right hand.

Hill, in describing hail-stones and tornadoes in India, explains them on the principle of the great diminution of temperature upwards in the air, but a critic, in combating this theory, objects to the high and low stations selected to show temperatures.

The so-called "weather plant" of the tropics has passed through the process of investigation with the usual result. It appears surprising that in these days it should be believed that any plant or animal can foretell weather 48 hours in advance, particularly after considering the vast amount of proof as to the enormous rapidity with which weather-changes progress from day to day.

Hugo Meyer, in treating the precipitation of central Germany for the ten years ending in 1885, pertinently remarks that the same significance does not attach to the same rainfall for all places and different times of the year, for this average value is not the amount most likely to fall in any particular interval of time, since there is a limit to the extent of the negative deviations on one side—that is, 0 or no rainfall, while on the positive side there is no limit. The most probable depth of rainfall, therefore, is less than the mean value, the preponderance of negative over positive deviations being about 10 per cent. and sometimes as great as 20 per cent.

Professor W. M. Davis wrote an interesting review of Professor Ferrel's popular treatise on the winds, published a year ago. Commenting on the review, the editor of *Meteorologische Zeitscrift*, Vienna, remarks on a very important omission in the treatise, namely, the absence of all reference to the diurnal variation of the wind and the many interesting relations it bears to other phenomena, a notable omission in a treatise specially devoted to winds. The treatment of the monsoon wind and its relation to the general circulation is highly commended by the editor, and indicated as being all new.

Your Vice-President has elsewhere expressed his opinion that monsoon winds, applying the term by liberal construction to signify winds which recur with returning seasons, cannot with

any degree of correctness be asserted to prevail in the United States. It is true that the prevailing surface winds of the greater part of the United States come from the western quadrants—that is, between southwest and northwest—and so are in substantial harmony with the general atmospheric circulation as shown by the upper-wind currents of Mount Washington (from the northwest) and Pike's peak (from the southwest). But, apart from the easterly and northeasterly trades on the Florida coast, it appears from the records that in no case for any considerable section of the country do 50 per cent of the winds blow, for any consecutive number of months, either from any single point or from two neighboring points of the compass. Occasionally, however, the local configuration of the country is such that winds are drawn up or down valleys, and, being diverted from their free and proper direction, the wind in such cases follows the trend of the valley or depression.

In general your Vice-President would feel inclined to refer only casually to the work proceeding from the Bureau over which he has the honor to preside, but this year has been marked by special researches and investigations of general interest. As the work of investigation has been entrusted to the professors of the Signal Service, due credit should not be refused them from their own official chief.

Special reference should be made to the work of Professor Charles F. Marvin, whose successful experiments on wind pressures and velocities have attracted the attention of experts both in Europe and in this country. Unfortunately there was available only a small sum (about one hundred dollars) for the expense of experiments, but with this petty sum, supplemented by his ingenuity, Professor Marvin has very satisfactorily determined the coëfficients of the various forms of the Robinson anemometer, with which instrument the velocity of the wind is very generally determined. Following these investigations, the Royal Meteorological Society of England reopened the question, which, after a costly set of experiments with results widely differing from those of Professor Marvin, had been considered closed.

The general results of these researches, which are believed to be sufficiently definite for general questions, are not only prized by the scientist, but they are of value to the engineer and the builder. Indeed, to all interested in costly structures or extended works liable to harm from wind pressures, the factor of safety is

a matter of no small pecuniary importance. These experiments show that, as was formerly believed to be the case, the wind pressure varies as the square of the velocity of the wind, expressed in miles per hour; but a most important fact has developed, namely, that the pressure in pounds per square foot is equal to the miles of hourly velocity multiplied by 0.004 instead of 0.005, as was formerly assumed.

Professor Marvin was not content with one system of experiments, but he further attacked the problem in a direct manner by a method which checked and verified his experiments with the whirling machine. On the summit of Mount Washington, at an elevation of 6,300 feet, he obtained simultaneously and under the same conditions, by automatic and electrical apparatus, continuous registration of the pressure of the wind in pounds per square foot and of the velocity in miles per hour.

The results thus verified can be considered as conclusive from a general standpoint. The corrections for the Robinson anemometer thus determined from these experiments are comparatively unimportant at low velocities, say from 10 to 15 miles per hour, being only a fraction of a mile per hour. The uncorrected velocities, however, are in all cases too large, and by greater and greater amounts the higher the velocity. At 60 miles per hour the observed velocities are about 12 miles per hour too high, and for an indicated velocity of 90 miles the experiments show that the actual velocity is but a fraction over 69 miles per hour.

The anemometer formula found to satisfy most closely the entire range of experiments has the following form for velocities in miles per hour:

$$\text{Log. } V = 0.509 + 0.9012 \text{ log. } r.$$

This difference indicated by the formula may seem small and insignificant, as it is in the case of light winds, but at very high velocities the differences are very great. For instance, an actual velocity of 60 miles per hour may occur at some time in almost any locality of the United States for a few minutes, and even greater velocities are occasionally reported, apart from severe tornadoes. Under the old coëfficients for the Robinson anemometer an actual velocity of 60 miles per hour would have been reported as 77 miles per hour, which under the old factor of 0.005 would mean a pressure of 29.6 pounds per square foot; but when considered with reference to the true velocity of 60 miles, under

the new factor of 0.004, the pressure would only be 14.4 pounds per square foot—a reduction of over 50 per cent from the pressure-values formerly accepted.

Professor Marvin has undertaken to verify, and also to extend to even lower temperatures, the observations of Regnault as to the pressure of aqueous vapor at low temperatures, especial attention being given to temperature conditions from 0° centigrade to — 50° centigrade. These observations disclose, below 0° centigrade, small but constant differences from the values assigned by Regnault.

In all this work Professor Marvin has shown such ingenuity of resource, such skill in adapting means to the end, and such deftness in improvising and manufacturing the requisite instruments as have elicited commendation from all who have seen his work and followed his methods. Your Vice-President alludes to this not only to give that credit rightfully due to Professor Marvin, but to illustrate this as a type of the highly important work which is being done in all branches of science here in Washington by young men sometimes illy equipped as to means, and still more illy paid. Men engaged in work of original investigation should receive higher pay than clerks in charge of routine duties; but unfortunately the majority of them do not.

The work of Professor Hazen in charting tornadoes and in determining their relative frequency and severity is directly in the line of the Geography of the Air.

Great attention had previously been given to this subject by Lieutenant John P. Finley, who, with indefatigable industry, had accumulated an enormous mass of data relative to these violent outbursts of nature's forces. The figures and deductions previously put forth under the authority of the Signal Service having been questioned, the Chief Signal Officer felt obliged, in view of the growing practical importance of the question, as indicated by the great sums annually paid out in the Ohio valley and in the trans-Mississippi region for protection against tornadoes, to reöpen the subject. Instructions of the most conservative character were given to Professor Hazen to determine carefully the prevalence and number of tornadoes in the United States, the areas devastated by them, and the number of lives lost annually. This work was carefully scrutinized during its progress to see that it should be devoid of theory and rest on the solid basis of fact. The results are most assuring to every

one, and must serve to allay the unreasonable fears of the inhabitants of the so-called "tornado districts." It appears that there is no part of the United States in which annually more than one square mile of devastation or severe destruction can be expected for each 185,000 square miles, although cases of *limited destruction* may occur annually for about every 5,000 square miles of area. In no state may destructive tornadoes be expected, on an average, more than once in two years; and the area over which total destruction can be expected is, as shown by the foregoing figures, exceedingly small, even in localities most liable to these violent storms. The annual death casualties from tornadoes have averaged, in the last 18 years, 102 annually; but it is believed that the death rate from lightning is greater than that from tornadoes, since during March to August, 1890, the names of 110 are on record who have lost their lives by lightning, although the data are incomplete, especially as regards the southern states. These statistics cannot be passed by lightly, however, and it is doubtful if in the main they are much in error. By them it appears from five years' record that the average annual death rate by lightning in the United States is 3.8 per million of inhabitants, or 0.2 above the average. In Sweeden, for sixty years, the average has been 3.0; in France, for forty-nine years, 3.1; in Baden, for seventeen years, 3.8; and in Prussia, for fifteen years, 4.4 per million.

Other figures, given by a life-insurance agent in St. Louis, which the author claims to have compiled with great care, place the average annual rate of death from lightning in the United States at 206, being more than double the deaths from tornadoes. It must be understood that these figures are not vouched for, and must be very cautiously received, as originating with companies interested pecuniarily in the statistics.

On the whole, therefore, it may be safely assumed that tornadoes are not so destructive to life as thunder-storms.

Professor Thomas Russell has formulated a method for prediction of cold waves. They always occur after "lows" and before "highs," and different cold waves vary in extent from three "units" to sixty. A "unit" of temperature-fall is taken as a fall of twenty degrees over an area of 50,000 square miles.

The temperature-fall curves in the United States are approximately elliptical in shape. Perfect ellipses represent actual temperature falls with an error not exceeding six degrees in

most cases. These fall lines are intersections of planes with a cone which graphically represents the totality of temperature-fall, the contents of the cone being equal to the area of its base multiplied by its altitude, which is the greatest fall in temperature at the center of the cold wave.

A formula has been devised, based on 127 special cases, representing the amount of fall in terms of the amount of barometic depression in a "low," and the amount of excess if a "high," and the density of the isothermal lines in the region.

From proper consideration of the type of low area, shape of isobars, and position of the long axis, definite conclusions can be drawn as to the subsequent shape of the elliptical twenty-degree temperature-fall area and its position.

A method has been devised, also by Professor Russell, for determining the maximum fall of temperature at the center of the cold wave. The maximum fall and extent of fall being known, from suitably prepared tables, the area of twenty-degree fall can be derived. Previously prepared pieces of card-board are laid in the proper position on a map of suitable scale, and lines drawn around them. Between the line representing the twenty-degree fall and the center, the other falls of thirty degrees, forty degrees, etc., are sketched in.

The foregoing sketch of the geography of the air may appear too superficial and limited for the purposes of this Society, but its further elaboration was impracticable. Indeed, the subject of meteorology could hardly have been touched upon this year had it not been for the courtesy of Professor Russell in placing at my disposal notes upon translations from foreign publications, especially from the German; which publications I have been unable to examine save in a casual way.

The address, as it is, is submitted only in the hope that it may serve, if no other purpose, at least to indicate the great interest which now obtains in the geography of the air, and which manifests itself in the production of meteorological pamphlets and publications too numerous to permit any one charged with important executive duties to examine them all, even in a non-critical way.